THE INNOVATION CATALYST

November 2022

IN THIS ISSUE:

TECH TRANSFER TIP

with Agreement Manager Erin Majerowicz:

Take the time to get to know your Technology Manager and SPO's Marketing Team. We're often asked to recommend innovators and technologies for agency activities and webinars. While we don't play favorites, we're more likely to recommend innovators who we know are enthusiastic about getting their technology out there!

UPCOMING EVENTS:

INNOVATOR HOUR

TUESDAY, NOVEMBER 8, 2022

1:00–2:00 P.M.

STRATEGIC PARTNERSHIPS OFFICE

NP-2022-11-896-GSFC

Inventor of the Month

Simulation Tool Helps Increase SmallSat Reliability

SmallSats can be very complex systems, harnessing many components within multiple subsystems that must mesh together perfectly for the spacecraft to operate for years. If it breaks down in space, there is no prospect for repair. Considering the cost and time involved in designing and building a SmallSat, every developer must answer a critical question: Will what they've designed on the drawing board – before they have any of the physical hardware components – actually work?

"What you don't want to happen," said Luis Santos Soto, chief engineer of the Small Satellite Project Office at Goddard, "is to put all your components together to complete the SmallSat only to find there is a problem. Although having no issues during I&T [Integration and Testing] is incredibly difficult to achieve, the risk can be considerably reduced from the software standpoint if we have a digital equivalent for the system to enable early software development."

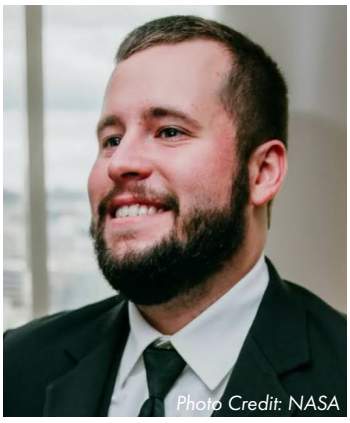


Photo Credit: NASA

John Lucas, deputy lead of the McBride Testing and Research (JSTAR) team, mission systems engineer for the [Geostationary Transfer Orbit Satellite] (GTOSat) mission and computer engineer at Goddard's Katherine Johnson IV&V Facility has the answer. He and his JSTAR team have developed the NASA Operational Simulation for Small Satellites (NOS^3), which is a suite of software tools that allows a SmallSat developer to verify and validate all the test flight and ground flight software and component hardware in the spacecraft before it is built and assembled. NOS^3 is a Goddard technology that holds several patents and is available commercially for licensure.

"What NOS^3 allows you to have is a spacecraft in your laptop," said Lucas. "Instead of having the full physical SmallSat or without having to actually build an entire spacecraft, you can actually run and simulate your entire spacecraft, including orbital dynamics, ground and flight software as it fits in space, just on any old laptop that is laying around. NOS^3 is just another tool in your toolbox to really do your design and testing of the spacecraft."

NOS^3 was born seven years ago out of NASA's Simulation to Flight (STF-1) CubeSat mission. Under NASA's CubeSat Launch Initiative, Goddard teamed with West Virginia University to build and launch the STF-1 spacecraft. The main goal of the mission was to fully demonstrate the Operation Simulation technologies in the NOS^3. All the needed software development, mission operations/training, verification and validation, test procedure development, and software check-out systems grew from a background of developing simulations on the James Webb Space Telescope, the Global Precipitation Measurement mission, the Juno spacecraft mission to Jupiter, and the Deep Space Climate Observatory.

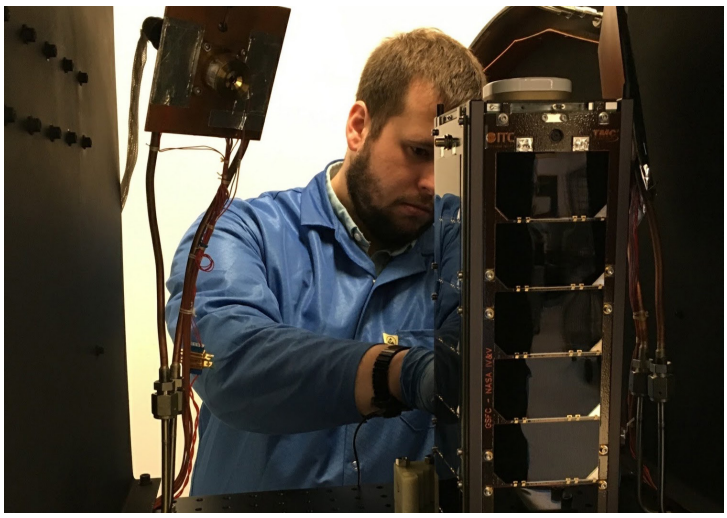
"NOS^3 is really an augmentation for your development flow," said Lucas. "We've built spacecraft before and we've had this kind of technology and simulation capability, but NOS^3 really allows us to expedite the development process. Now, we don't have to [physically] break things to see their response on the spacecraft."

"The other beauty of NOS³ is you can actually have the [physical] hardware in the loop as well," added Santos Soto. "You can start with all the software simulation and everything that can be done on your laptop. But eventually, when you get all of your components, you can potentially plug them into the NOS³ system as well. So, you can have a combination of real hardware and simulation software talking to everything on the NOS³."

One of the other advantages of NOS³ was during the COVID-19 pandemic, when commercial-off-the-shelf parts for satellites were delayed due to production and shipping issues, and developers had to wait months for products. Using NOS³, satellite developers could simulate components until they arrived.

"The really nice thing about NOS³ is it has allowed NASA to continue satellite development during the pandemic," stressed Lucas. "That was extremely critical during COVID because we did not get a single component delivered on time due to the nature of the world. NOS³ allowed us to basically start doing all the coding for both the flight and ground software, as well as run the spacecraft simulation for the developers at all of the NASA centers so they could continue to do SmallSat development and build spacecrafts."

"NOS³ saves you time and money," said Santos Soto. "Now, you don't have to wait until the hardware components show up to start coding. When they arrive, all you have to do is test the developed software with the actual components and there are no unforeseen issues."



John Lucas, Photo Credit: NASA

John Lucas in the lab, Photo Credit: NASA

Flight and Ground Software Components That Interact with NOS³

NOS³ is an open-source software that integrates with a variety of key flight and ground software tools, as well as hardware simulation platforms such as:

- NASA Operational Simulator of Small Satellites (NOS) is the core technology for NOS³ that provides the connectivity between the flight software and the simulated hardware components.
- NASA's Core Flight System (cFS) is a reusable flight software framework that is used as the base system for flight software.
- Simulated hardware components serve as a virtual hardware model that connect to the NOS engine and provide the hardware input and output to the flight software.
- Oracle VirtualBox and Vagrant allows a computer to set up the virtual machinery necessary to run the applications associated with the NOS³ suite.
- COSMOS (Open Source Managed Operating System) is a ground system software used to provide command and control of the flight software.
- OIPP (Orbit Inview and Power Prediction) is a planning tool developed by members of the NASA IV&V team that allows the ground station to know when the satellite will be in view, as well as when the satellite will be in direct sunlight. This allows the IV&V team to plan power usage and communication times.
- 42 is a NASA developed visualization and simulation tool used for spacecraft attitude and orbital dynamics. 42 provides magnetic field and positional data inputs to the magnetometer and GPS simulators.

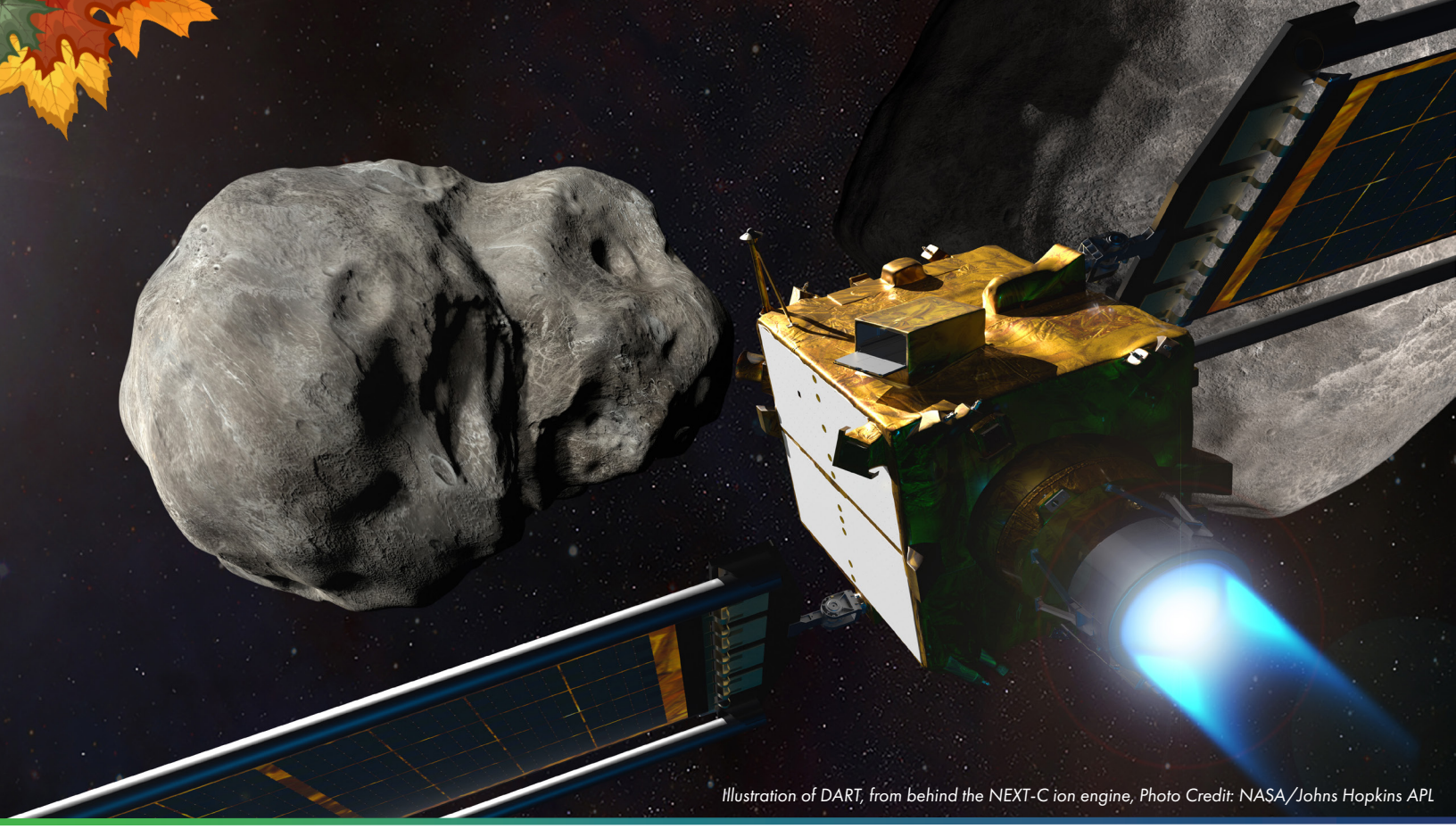


Illustration of DART, from behind the NEXT-C ion engine, Photo Credit: NASA/Johns Hopkins APL

Bullseye! With Goddard's Help, DART Spacecraft Hits Asteroid

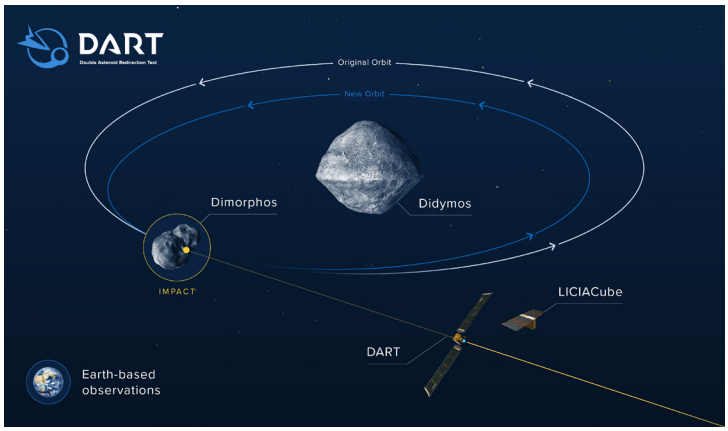
In the 1998 movie *Armageddon*, Bruce Willis, Billy Bob Thornton, and Ben Affleck are blue-collar workers sent by NASA to stop a gigantic extinction-level asteroid on collision course with Earth. That theme of a huge unstoppable object hurling towards Earth to destroy humanity has played out in several other movies, including the sci-fi classic, When Worlds Collide, and, most recently, Don't Look Up. So, is this just Hollywood or can something like this actually happen, and what can NASA do about it?

While a relatively small asteroid of approximately 500 feet can carry enough energy to cause widespread damage around the impact site, NASA estimates that the chances of a large asteroid impacting Earth on any given day are very small. However, leaving nothing to chance, NASA led an international and commercial effort to both detect and track potentially hazardous asteroids, and to test technologies to mitigate or avoid an asteroid hit to Earth.

On September 26, using a "kinetic impactor," NASA's Double Asteroid Redirection Test (DART) spacecraft successfully targeted and hit a binary asteroid system system named Didymos that was passing relatively near Earth, but did not pose any threat. A binary asteroid is a system of two asteroids orbiting their common barycenter. A "kinetic impactor" is a high-velocity spacecraft that deflects an asteroid by ramming it, thus altering the smaller asteroid's orbit so it misses Earth. The key DART instrument for "kinetic impact" is NASA's Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO), a sensor that enables the needed contact by tracking the asteroid during high-speed approach.

DART's $325-million dollar "kinetic impactor" mission to deflect the smaller asteroid's orbit was intended as a dress rehearsal for the day a real killer rock potentially heads our way. While not on a path to collide with Earth, DART targeted a double (or binary) asteroid

system, which was composed of Didymos – a large asteroid – and Dimorphos, a smaller asteroid which orbited around Didymos. The mission was for DART to slam into Dimorphos head-on, thus changing its orbit around Didymos by an amount measurable from Earth-based telescopes and radar. Aside from movies, nothing like this has ever been attempted before.



The effect of DART's Impact on Dimorphos, Photo Credit: NASA/Johns Hopkins APL

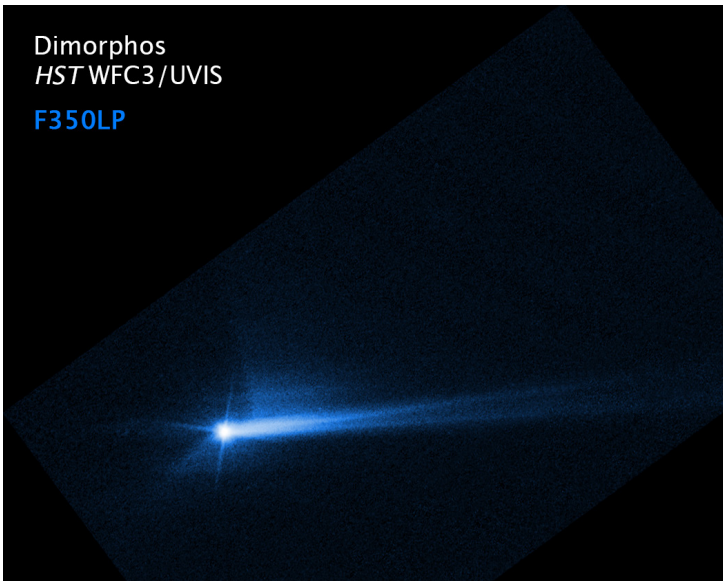
DART was led by NASA's Planetary Defense Coordination Office (PDCO), which is supported by several NASA Centers, the Johns Hopkins Applied Physics Laboratory, the European Space Agency (ESA), and several U.S.-based institutions. NASA established the PDCO to manage and coordinate planetary defense against hazardous objects like asteroids and comets that come within 30 million miles of Earth's orbit.

Goddard played a critical role in the DART mission. The job of engineers and scientists at Goddard was to check the flight path of the mission and run computer simulation models that predicted how DART's impact would change the orbit of Dimorphos around Didymos.

"The role of our Goddard team, which includes myself, Joshua Lyzhoft and Bruno Sarli, was to develop and maintain simulation software designed to run a series of independent checks on the mission's trajectory calculations," said Brent Barbee, dynamics verification and validation lead of the DART investigative team. "Those simulations were designed to verify the mission met its requirements in terms of early interplanetary trajectory planning and shows how DART's impact changes the binary asteroid's mutual orbit. In terms of what we have been planning to do for the past several years, so far DART has been an astounding success. I can't think of anything that could have gone better up to this point."

"We can all breathe a sigh of relief as we become more confident that Earth, during another time perhaps, will be safe from an Armageddon-like impact of large space rocks," added Goddard Center Director Dennis Andrucyk. "The DART mission accomplished its objective: crash into an asteroid and redirect it as a test of planetary defense. It's a novel mission, and one that may prove more useful than we know. Furthermore, Goddard played its part and will continue to do so as we observe the results of the impact."

Since DART first impacted Dimorphos about 6.8 million miles from Earth, Barbee and Lyzhoft have been working with astronomers using ground-based telescopes and radar from around the world to measure the smaller asteroid's change in momentum. Analyzing some of the first observations, it was estimated that the amount of dust and vaporized material from the impact on Dimorphos created a comet-like tail that is more than 6,000 miles long.



Post-impact View From Hubble, Photo Credit: NASA/ESA/STScI/Hubble

"Prior to the impact, we simulated a variety of different configurations for how the asteroid system might react; things like what if the spacecraft hits off center or even just kind of grazes the asteroid," recalled Barbee, of the DART mission that started in 2015. "It sure looks like the DART spacecraft hit Dimorphos dead on target as far as we can tell. Already, from the first images that

NASA's DART Spacecraft Launches in World's First Planetary Defense Test Mission, Photo Credit: NASA/Bill Ingalls

have been released, we are starting to get the very first observational data back from the mission. Then, we will build our very best computer models of exactly how the [asteroid] system behaved and exactly how DART impacted it."

Barbee said they are not only learning about how DART changed the trajectory of the asteroid system but also about the makeup of asteroids themselves and how they form in the first place. The DART mission is already starting to teach scientists more about the precise structure of asteroids.

"We are studying images of Didymos and we are already seeing some really interesting features on its surface that tell us things about its structure and formation history," noted Barbee. "For the most part, we don't think asteroids are like solid bricks, but how much strength do they have? Some scientists theorize that asteroids are rubble piles only loosely held together by mutual gravity. So, that is one of the more interesting things that we are investigating with the mission data. Just over the past few days, we are already getting some fascinating data about the asteroids."

Barbee said beginning this fall and going into next spring, they plan on publishing a whole series of brand-new peer-reviewed journal articles documenting the results of the DART mission. In 2026, NASA plans to partner with ESA on its Hera mission to rendezvous with the Didymos-Dimorphos asteroid system in space. By venturing up close to the binary asteroid system, Hera will be able to perform its own "crash scene investigation" of the DART impact effects on the asteroid's surface in detail.

"We are going to do our absolute best to compare what Hera learns from the information it gathers to the data we generated from DART," said Barbee. "We are going to go back and revisit the results that we are generating now prior to Hera and see what more we can learn about the DART mission results, and asteroids in general, from Hera. In the years to come, I am very hopeful that we will have a whole array of planetary defense test missions that will get us better prepared to deal with increasingly challenging classes of asteroid and comet threats."

THE STRATEGIC PARTNERSHIPS (SPO) OFFICE PRESENTS

INNOVATOR HOUR

Have questions about protecting your innovation?
Want to learn more about how to submit New Technology Reports?
Have general questions about technology transfer and partnerships?
Sign up for a one-on-one 20-minute timeslot with a SPO representative.
Meetings will be held virtually via Microsoft Teams.

NEXT SESSION: **TUESDAY, NOVEMBER 8, 2022**
1:00-2:00 P.M.

Available Timeslots
1:00-1:20 P.M.
1:20-1:40 P.M.
1:40-2:00 P.M.

How to Sign Up

To register for the upcoming session and secure your timeslot, complete the registration form.

Q AND A

with **JOSH**LEVINE

Photo Credit: N4 Solutions

How Goddard Licenses Your Invention

One of the main functions of Goddard's Strategic Partnerships Office (SPO) is to market and license Goddard-developed technologies and innovations to private industry. Through licensing agreements, private companies from all over the U.S. have been able to commercialize Goddard technologies. A licensing agreement is a legal document that spells out the terms and conditions allowing a company to turn a NASA technology into a commercial product. Josh Levine, technology manager at SPO, sat down with The Innovation Catalyst to discuss how SPO markets and licenses Goddard innovations.

What is the licensing process?

Basically, all our technologies are published on NASA's website. So, we have what is called TOPS, short for Technical Opportunity Sheets, that summarizes available technologies for licensing. Interested parties can go to the website and apply for a license for any available technologies listed. Our office reviews the licensee application and then, we contact the applicant to inform them of our acceptance. We connect you with inventors on campus so you can know more about it.

What types of licensing does NASA offer to private industry?

There are a couple of license types. One is called an Evaluation License, which gives another party the ability to evaluate our technology to determine if they believe they can commercialize it; it does not give you the right to sell it. But we can grant the right for them to develop it and see if it is a good fit for their business. The Evaluation License has a one time fee for six months up to two years.

For small businesses that are just starting up, we have what we call a Startup License. The advantage of that license is there are no upfront costs and it can be executed quickly. Although there is no initial fee, unlike the Evaluation License, the Startup License grants permission to sell and has standardized running royalties on

the backend that are based on those actual sales. At a minimum, after three years, the licensee has to start paying royalties to NASA but there are zero upfront costs.

And then, we have something called a Commercial License, which grants the right to sell a patented NASA technology. It is different from the Startup License in that the royalty terms are all negotiable. This includes an annual minimum payment to incentivize the licensee not to sit on the patent. These licenses come in two flavors: exclusive and non-exclusive. Most of what we do is non- exclusive, which means you can license one technology out to multiple companies. Exclusive would mean that only one company can license the technology. If the company wants an Exclusive License, there are some extra requirements. NASA has to post it publicly and there is a comment period. The licensee also has to have some sort of business case for it. So, we tend to do fewer of those.

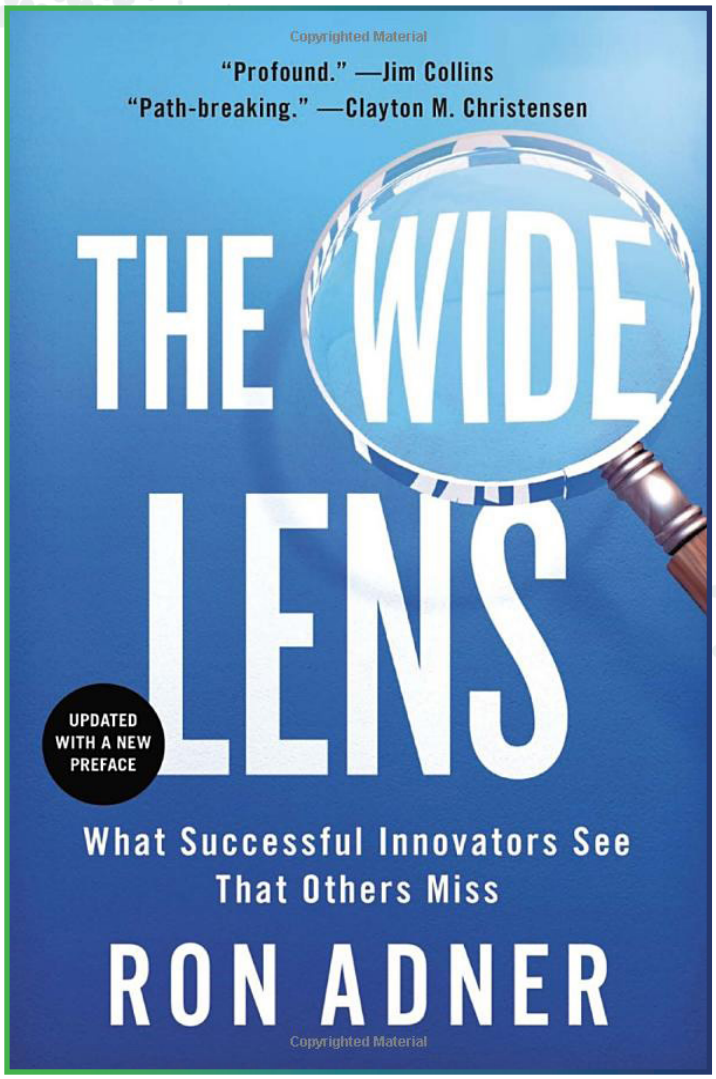
There is also another wrinkle, known as a Partially Exclusive License. Let's say, you have a company that is utilizing your technology in a particular space. For example, a food company wants to use your technology in their food application. You can do a Partially Exclusive License and grant them the exclusive right to use NASA's patent, but only for food applications.

What is the condition of licensing technology, if a contractor is involved in the NTR?

This gets complicated, and it could depend on the kind of contract they have with NASA. If it is a large entity, then NASA owns the invention, but then that company can request a waiver to elect title to the invention. If it is a small business, then they typically will have the right to elect title, if they wish. However, NASA will always retain a royalty-free license to utilize the invention for government purposes. When there are multiple outside entities with inventors involved with the intellectual property, determining ownership can get somewhat tricky. SPO works closely with the Office of General Counsel to resolve ownership rights for all NTRs we collect.

STRATEGIC
PARTNERSHIPS OFFICE

THE LITERARY X-CHANGE BOOK OF THE MONTH



How can great companies do everything right—identify real customer needs, deliver excellent innovations, beat their competitors to market—and still fail?

The truth is that many companies fail because they focus too intensely on their own innovations, while neglecting the ecosystems on which their success depends. In our increasingly interdependent world, winning requires more than just delivering on your own promises. It means ensuring that a host of partners—some visible, some hidden—deliver on their promises, too.

Rod Adner draws on over a decade of research and field testing to reveal the hidden structure of success, from Michelin's failed run-flat tires to Apple's path to market dominance. The "Wide Lens" offers a powerful new set of frameworks and tools that will multiply your odds of innovation success.

(Publisher's Summary)

We Want to Hear From You

Have a suggestion? Want to leave a review of the latest book you read from the X-Change? Send your comments to rafael.j.mcfadden@nasa.gov. We'd love to hear from you.

WHAT IS THE LITERARY X-CHANGE?

In 2021, the Strategic Partnerships Office (SPO) launched a community library with a little help from Tor Books. Goddard has partnered for years with Tor, a leading publisher of science fiction, by connecting them with subject matter experts to promote the science in "science fiction." Located in the lobby of Building 22, The Literary X-Change is available to the entire Goddard community. Here's how it works:

TAKE ONE

If a book strikes your fancy take it. Read it, enjoy it, and—when you're done—share it with a friend or bring it back to the X-Change.

GIVE ONE

Everyone can pitch in to keep the library stocked. Bring books you'd like to share with the Goddard community when you can and continue being a friend of The Literary X-Change!